LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

1

LA-UR -86-3692

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--86-3692

DE87 001985

TITLE: COMPARISON OF A TRAC CALCULATION TO THE DATA FROM LSTF RUN SB-CL-05

AUTHOR(S): Frank Motley, Los Alamos National Laboratory
Richard Schultz, Idaho Engineering Laboratory

SUBMITTED TO: Fourteenth Water Reactor Safety Information Meeting
October 27-31, 1986
National Bureau of Standards (NBS)
Gaithersburg, MD

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

COMPARISON OF A TRAC CALCULATION TO THE DATA FROM LSTF RUN SB-CL-05*

by

Frank Motley
Safety Code Development Group
Energy Division
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Richard Schultz
Idaho Engineering Laboratory
Idaho Falls, Idaho 83415

ABSTRACT

Run SB-CL-05 is a 5% break in the side of the cold leg. The test results show that the core was uncovered briefly and that the rods overheated at certain core locations. Liquid holdup on the upflow side of the steam generator tubes was observed. When the loop seal cleared, the core refilled and the rods cooled.

The TRAC results are in reasonable agreement with the test data, meaning that TRAC correctly predicted the major trends and phenomena. TRAC predicted the core uncovery, the resulting rod heatup, and the liquid holdup on the upflow side of the steam generator tubes correctly. The clearing of the loop seal allowed core recovery and cooled the overheated rods just as it had in the data, but TRAC predicted its occurrence 20 s late.

The experimental and TRAC analysis results of run SB-CL-05 are similar to those for Semiscale Run S-UT-8. In both runs there was core uncovery, rod overheating, and steam generator liquid holdup. These results confirm scaling of these phenomena from Semiscale (1/1650) to LSTF (1/48).

I. INTRODUCTION

Los Alamos National Laboratory and Idaho National Engineering Laboratory (INEL) are analyzing selected Large-Scale Test Facility (LSTF) experiments using the Transient Reactor Analysis Code (TRAC),[1] developed by Los Alamos. This report describes the results of the first LSTF test analyzed using TRAC. The LSTF is a large scale (1/48) integral-test facility for the study of pressurized water reactors (PWRs) during small-break loss-of-coolant accidents (SBLOCA) and anticipated reactor transients. All the major components of the primary and secondary systems of a PWR are modeled by the LSTF. The available power is limited to 14% of scaled full power so that for steady-state operation the loop flow is reduced to maintain

* Work performed under the auspices of the US Nuclear Regulatory Commission

the correct temperature rise through the heated core. The secondary pressure is increased to reduce the primary-to-secondary heat transfer to 14%. The LSTF was built by the Japan Atomic Energy Research Institute (JAERI) and the test results are shared with the US Nuclear Regulatory Commission (NRC) according to terms of a bilateral agreement.

The main objective of Run SB-CL-05 was to investigate the thermal-hydraulic mechanism of early core uncovery and heatup caused by manometric imbalance due to liquid holdup in the upflow side of the tubes of the steam generators.[2] The results show that the test demonstrated all of the phenomena expected. The core uncovered briefly and the rods overheated at certain core locations. The overheating was limited to 100 K. Liquid holdup was observed in the upflow side of the steam generator tubes. When the loop seal cleared, the core refilled and the heater rods cooled. Throughout the remainder of the test the core was cool. Because this test was one of the first performed in the LSTF, some test instruments failed and others were subject to errors.

Early core uncovery and heater rod heatup were first observed in the Semiscale Mod-2a test facility in Run S-UT-8.[3] These results were unexpected and further tests were conducted in Semiscale to study these phenomena.[4] Liquid holdup and core uncoveries were observed in the additional tests. The small scale of the Semiscale facility (1/1650) was of concern in applying the test results to PWRs.

II. TRAC MODEL DESCRIPTION

The TRAC input model of the LSTF is very detailed and describes the primary system and the secondary system to the steam valves.[5] The emergency core-cooling system (ECCS) is modeled as a boundary condition that includes high-pressure injection (HPI), accumulator, and low-pressure injection (LPI) flows. Figure 1 shows the TRAC model of the LSTF. There are 41 components and 50 junctions. The detailed vessel model is shown in Fig. 2. There are 325 computational cells in the model. This noding is considered very detailed for analysis of a SBLOCA. The three inner rings of the vessel allow representation of each of the radial power zones in the core. The six core levels accurately model the axial heat flux shape. Six pipes model the guide tubes which connect the upper head (three top levels) to the upper plenum. The detailed description of the TRAC input model is contained in Ref. 6. TRAC-PF1/MOD1 version 12.7 was used for this calculation.

III. INITIAL AND BOUNDARY CONDITIONS

Steady-state initial conditions for the LSTF are similar to normal operating conditions in a PWR except that the loop flow and the core power are reduced to 14% of the scaled PWR values. This is necessary to maintain the correct temperature rise in the core with the limited power available in the LSTF. The secondary-side pressure in the steam generators was increased to reduce the primary-to-secondary heat transfer. The comparison of measured to calculated initial conditions is shown in Table I. There is good agreement in all comparisons. The calculated hot-leg temperatures are slightly high because of the lower loop flow and the heat losses in the test facility that were not accounted for in the TRAC model. The heat losses are not considered to be important for this transient. The core bypass flow was based on the results of a special leakage test. All the bypass in the vessel is assumed to occur between the downcomer and the upper head.

The boundary conditions imposed during the transient were taken from the test data. The power to the core is held at the steady-state level until 45 s after the break opens; then it follows a calculated radioactive decay. The pump speed is increased rapidly after the break opens until it doubles at 15 s; then it is controlled to model pump coastdown. This procedure is an attempt to pick up the transient as if it had started at full power and flow conditions. The ECCS flows into the system were summed and provided to the ECCS locations in the input model. The steam-generator secondary main steam valves close at 15 s. The secondary-side pressure is controlled by the relief valves, which are set to open at 8.03 MPa and to close at 7.82 MPa. The steam-generator feedwater flow is supplied to the calculation in the same manner as during the test.

IV. DEFINITIONS OF COMPARISON DESCRIPTORS

The agreement between the data and the TRAC-calculated results is characterized by four descriptors: *excellent agreement*, *reasonable agreement*, *minimum agreement*, and *insufficient agreement*. Each descriptor is defined in the following paragraphs, along with the consequences for future application of the code in the given area being characterized and the perceived need for additional code development.

Excellent agreement is an appropriate descriptor when the code exhibits no deficiencies in modeling a given behavior. Major and minor phenomena and trends are predicted correctly. The calculated results are judged by the analyst to be close to the data with which a comparison is being made. If the uncertainty of the data has been identified and made available to the analyst, the calculation will, with few exceptions, lie within the uncertainty band of the data. The code may be used with confidence in similar applications. Neither code models nor the facility noding model requires examination or change.

Reasonable agreement is an appropriate descriptor when the code exhibits deficiencies, but the deficiencies are minor; that is, the deficiencies are acceptable because the code provides an acceptable prediction of the test. All major trends and phenomena are predicted correctly. Differences between the test and calculated traces of parameters identified as important by the analyst are greater than those deemed necessary for excellent agreement. If uncertainty data are available, the calculation frequently will lie outside the uncertainty band. However, the analyst believes that the discrepancies are insufficiently large to require a warning to potential users of the code in similar applications. The assessment analyst believes that the correct conclusions about trends and phenomena would be reached if the code were used in similar applications. The code models and/or facility noding model should be reviewed to see whether improvements can be made.

Minimal agreement is an appropriate descriptor when the code exhibits deficiencies and the deficiencies are significant; that is, the deficiencies are such that the code provides a prediction of the test that is only conditionally acceptable. Some major trends or phenomena are not predicted correctly whereas others are predicted correctly. Some TRAC-calculated values lie far outside the uncertainty band of the data with which a comparison is being made. The assessment analyst believes that incorrect conclusions about trends and phenomena might be reached if the code were used in similar applications. The analyst believes that certain code models and/or the facility noding model must be reviewed, corrections made, and a limited assessment of the revised code or input models made before the code can be used with confidence for similar applications. A warning should be issued to the TRAC user community that the user applying the code in similar applications risks drawing incorrect conclusions. This warning should stay in force until the identified review, modification, and limited assessment activities are completed and the resultant characterization descriptor is "reasonable" or better.

Insufficient agreement is an appropriate descriptor when the code exhibits major deficiencies; that is, the deficiencies are such that the code provides a prediction of the test that is unacceptable. Major trends are not predicted correctly. Most TRAC-calculated values lie far outside the uncertainty band of the data with which a comparison is being made. The assessment analyst believes that incorrect conclusions about trends and phenomena are probable if the code is used in similar applications. The analyst believes that certain code models and/or the facility noding model must be reviewed, corrections made, and a limited assessment of the revised code or facility noding model made before the code can be used with confidence for similar applications. A warning should be issued to the TRAC user community that the code must not be used for similar applications until the identified review, modification, and limited assessment activities are completed and the resultant characterization descriptor is "reasonable" or better.

V. COMPARISON OF TRAC-CALCULATED RESULTS TO LSTF DATA

The TRAC calculation proceeds in a manner similar to the experiment. The comparison of the sequence of events is shown in Table II. Most of the small differences in timing between the test data and the TRAC calculation can be explained by the fact that the test data are from Ref. 2 and the TRAC input was taken from the data tape. The major difference is the delay of 20 s in the core uncovery and loop seal clearing. Because Run SB-CL-05 was one of the first tests performed in the LSTF, some of the data have zero offsets and unexplained sudden value changes.

The system pressure behavior is similar at all locations, so only the upstream-break pressure is compared (Fig. 3). There is excellent agreement until 23 s, when the rate of pressure decrease slows in the experiment. At 80 s the data and the calculation are in agreement again and remain in reasonable agreement throughout the remainder of the transient. The increase in rate of pressure decrease at 160 s in the data and 180 s in the calculation corresponds to loop seal clearing. The liquid temperature upstream of the break (Fig. 4) is in reasonable agreement with the data and indicates that there is liquid with significant subcooling at the break until 50 s. The mass flow rates out of the break are compared in Fig. 5 and the integral mass losses from the system are compared in Fig. 6. There is reasonable agreement between the data and the calculation. During the first 50 s the calculated flow decreases in a similar manner as the pressure, whereas the data indicate a much smaller change in the flow. One of the measured flows (FRE590) is derived from the catch-tank level change and, therefore, may not be able to follow the rapid changes in flow at the beginning of the transient. The integrated mass loss comparison (Fig. 6) indicates that the calculated mass loss until the time of loop seal clearing is 10% less than in the data. The difference in the system pressure between 23 and 80 s can be explained by the different steam generator secondary and upper head behavior in the calculation. The pressure in the secondary of the loop B steam generator is shown in Fig. 7. The TRAC input modeled the relief valve action based on information about set points and valve response; but, as the pressure comparison shows, there is insufficient agreement between the calculation and the data, which may be attributed to an inadequate characterization of the value. The loop A steam generator behaved in a similar manner. The periods of high secondary pressure are evident in the primary pressure (Fig. 3). These high secondary pressures are not sufficient to explain the primary pressure between 23 and 80 s. The draining of the upper head occurred later and at a lower pressure in the calculation because the initial temperature of the fluid in the upper head was too low and had insufficient agreement with the data. This temperature (Fig. 8) is a function of the downcomer to upper head leakage flow and heat transfer between the upper plenum and upper head. In the TRAC model, all the core bypass was assumed to be between the downcomer and the upper head. The special leakage tests to determine core bypass did not identify the specific leakage paths. Apparently much of the leakage was between the downcomer and the upper plenum because the measured initial upper head fluid temperature is closer to the core-exit temperature than the core-inlet temperature. The calculated upper head fluid temperature is equal to the core-inlet temperature. The earlier draining of the upper head in the experiment is shown in Fig. 9, which compares the upper head differential pressure. The data have a zero offset of 2 kPa and unusual initial behavior, but indicate that draining of the upper head begins earlier in the experiment. As will be shown later, the calculation drains the top of the steam generator tubes instead of the upper head. These disagreements in pressure and draining are ended before the core uncovery and, therefore, have no effect on the remainder of the calculation. Figure 10 shows the excellent agreement between the calculated and measured emptying of the pressurizer, with an apparent offset in the measurement.

The next series of plots shows the behavior in the vessel. The calculated downcomer liquid volume fraction is shown in Fig. 11. The measured and calculated downcomer differential pressures are compared in Fig. 12. The agreement is considered to be reasonable. In the calculation, the downcomer remained full until the loop seal cleared, but in the experiment the downcomer drained down to the nozzle level by 100 s and that remained constant until after the loop seal cleared. The voiding of the upper head in the experiment may have filled the top of the downcomer with vapor through the upper head leakage holes. The calculated core liquid volume fractions are shown in Fig. 13. The reasonable agreement between the calculated and measured core differential pressures is shown in Fig. 14. Initially, there is excellent agreement as the flow first increases and then decreases, but as core voiding begins the measured differential pressure decreases more rapidly than in the calculation. The core level is depressed until the loop seal clears and then the core is refilled rapidly. The slower calculated mass loss at the break explains the slower core level depression in the calculation and the later refill as the loop seal clears.

The temperature response of the heater rods is shown in the next series of plots. The maximum calculated temperature at any location on any of the heater rods is shown in Fig. 15. The temperature follows saturation except for the short period between 140 and 180 s when the core uncovers and some rod locations heat up until the core refills and the rods are again cooled. One rod from each of the three power zones was chosen as a comparison point for the measured and calculated temperatures at six axial locations. Figures 16, 17, and 18 show the temperatures for the intermediate, high, and low power zones respectively. There is moderate agreement between the data and the calculation. The calculated rod heatup is delayed but the temperature increase is correct. Inspection of all the measured rod temperatures shows considerable variation form rod to rod within the core at any given elevation so that the agreement between the calculation and the data shown in Fig. 16 through 18 is typical of the average.

The steam generator differential pressure measurement is divided into upflow and downflow sides of the tubes. The differential pressure instruments are connected to show a positive reading when the tubes are full of liquid. This method of instrumentation means that flow losses are added to the liquid head on the upflow side and subtracted on the downflow side. The comparison of the measured to calculated differential pressure for steam generator A upflow and downflow sides are shown in Figs. 19 and 20 respectively. After the initial deflections caused by the increase in the flow, both sides show that the calculation begins draining the tubes earlier than the data, showing minimal agreement between TRAC and the data. As discussed above, this is due to the lower initial temperature of the fluid in the upper head. After 80 s, the agreement improves to moderate. Comparison of Fig. 19 to Fig. 20 shows that the downflow side drains at 100 s, while on the upflow side some liquid is held up and maintains a differential pressure of up to 30 kPa until the loop seal clears. The differential pressures for the loop B steam generator are similar to loop A. The upflow and downflow sides are shown on the same plot separately for the data (Fig. 21) and the calculation (Fig. 22). Both of these plots clearly show the liquid holdup between 80 and 180 s. The comparison of Fig. 21 to Fig. 22 shows reasonable agreement except between 25 and 80 s, when the agreement is minimal as a result of the early draining in the calculation. The pressure difference between the upflow and downflow sides is up to 30 kPa.

The loop seal differential pressure also is split in two sections. The downflow section connects the steam generator outlet to the bottom of the loop seal. The upflow section connects the bottom of the loop seal to the inlet of the pump. As in the case of the steam-generator differential pressure, the loop seal differential pressure is composed of a liquid head and flow loss. The upflow and downflow sides differential pressures for loop A are shown in Figs. 23 and 24, respectively. The downflow side (Fig. 23) begins clearing at the same time in both the data and the calculation, but the clearing proceeds more slowly in the calculation than the experiment. The upflow side (Fig. 24) clears after the downflow side. The agreement in Figs. 23 and 24 is considered reasonable.

VI. REVIEW OF S-UT-8 RESULTS

The test and TRAC analysis results of S-UT-8[7] (a Semiscale run) are briefly reviewed here to compare with the results of SB-CL-05 for study of similar phenomena at two different scales. In the S-UT-8 experiment there were two core uncoveries (Fig. 25). The early core uncovery is of interest because it is caused by liquid holdup in the steam generator. There is reasonable agreement between the measured and predicted core levels. The calculated time of the first core level depression is delayed by 25 s. The rod temperature response at the 208-cm elevation is shown in Fig. 26. There was limited heatup during the early core liquid level depression. The predicted temperature increase was in reasonable agreement with the data even though the first heatup was delayed 50 s. The delay in core depression in the calculation may have been caused by the slower mass loss out of the break (Fig. 27). The clearing of the loop seal occurs at the same mass loss. The collapsed liquid level in the upflow and downflow sides of the intact loop steam generator is shown in Fig. 28. The liquid holdup or delay in draining on the upflow side of the steam generator is shown in both the data and the calculation. The level difference was 2.5 to 3.0 m. The calculated clearing of the upflow and downflow sides of the steam generator was delayed 50 s compared to the data.

Comparison of the behavior of S-UT-8 to SB-CL-05 shows very similar phenomena in both tests with some timing differences when this phenomenon occurred. The core uncovery was almost complete in both tests (Figs. 14 and 25). In response to the core uncovery, the cladding temperature increased by 100 K (Figs. 17 and 26). The loop seal clearing and core recovery occurred at the time that the primary inventory was reduced to 30% of the initial inventory (Figs. 6 and 27). The liquid holdup or delay in draining on the upflow side of the steam generator caused a pressure imbalance that was equivalent to 2.5 to 3.0 m of water (Figs. 23, 24, and 28). The similarity of phenomena in these two facilities builds confidence that these results can be expected to occur in a PWR. The Semiscale facility is a 1/1650 scale model and the LSTF is a 1/48 scale model. Scaling from Semiscale to the LSTF is an increase in scale of 35 times so that this is almost halfway to full scale. One of the important phenomena is the steam generator liquid holdup. Similar holdup has now been observed in the 6 tubes of Semiscale and the 141 tubes of LSTF. It is now more believable that holdup may occur in a full-scale steam generator with 3000 or more tubes. The ability of the TRAC code to calculate the phenomenon equally well in the two different scaled experiments confirms the scalability of the many models in the code that are important in calculating this small break.

VII. CONCLUSIONS

Experiment SB-CL-05 in the LSTF showed that, for a 5% cold-leg break, a core uncovery occurred and that during this uncovery the rod cladding temperatures increased by 100 K. The core uncovery occurred when the loop seal was full and a pressure imbalance between the upflow and downflow sides of the steam generator was the equivalent of 2.5 to 3.0 m of liquid. When the loop seal cleared, the core recovered and the rods cooled.

The TRAC calculation of this experiment was in reasonable agreement with the data. TRAC predicted all the major trends and phenomena but was 20 s late in the timing. The predicted liquid holdup on the upflow side of the steam generator was in agreement with the data. The manometric pressure imbalance from the liquid holdup caused the core to uncover and the rod cladding temperature to increase. The clearing of the loop seal relieved the pressure imbalance and allowed the core to recover and cool.

The similarity of Semiscale Run S-UT-8 to LSTF Run SB-CL-05 confirms the scaling of the small-break phenomena observed in these experiments. The scale change from Semiscale to LSTF is 35 times, which is close to the 48-times scale change between LSTF and full scale. The reasonable agreement between the TRAC code calculation and the experimental data of these two tests confirms the scalability and accuracy of the small-break modeling in the code.

REFERENCES

1. Safety Code Analysis Group, "TRAC-PF1/MOD1: An Advanced Best-Estimate Computer Program for Pressurized Water Reactor Thermal-Hydraulic Analysis," Los Alamos National Laboratory report LA-10157 MS (NUREG/CR-3858)(July 1986).
2. Personal Communication, K. Tasaka.
3. M. T. Leonard, "Vessel Coolant Mass Depletion during a Small Break LOCA," EG&G report EGG-SEMI-6010 (September 1982).
4. G. G. Loomis and J. E. Streit, "Quick Look Report for Semiscale Mod-2c Experiments S-LH-1 and S-LH-2," EG&G report EGG-SEMI-6884 (1985).
5. ROSA-IV Group, "ROSA-IV Large Scale Test Facility (LSTF) System Description," JAERI report JAERI-M 84-237 (1985).
6. F. Motley and R. Schultz, "A TRAC model of the Large-Scale Test Facility," Los Alamos National Laboratory report (to be published).
7. R. K. Fujita, "TRAC-PF1/MOD1 POSTTEST ANALYSIS OF SEMISCALE SMALL-BREAK TEST S-UT-8," Los Alamos National Laboratory report, LA-UR-85-961 (1985).

TABLE I

INITIAL CONDITIONS FOR RUN SB-CL-05

Parameter	Test Data	TRAC Results
Pressurizer pressure (MPa)	15.6	15.58
Loop A hot-leg fluid temperature (K)	599	601.8
Loop B hot-leg fluid temperature (K)	599	601.8
Loop A cold-leg fluid temperature (K)	565	565.0
Loop B cold-leg fluid temperature (K)	564	565.0
Core power (MW)	10	10.04
Core inlet flow (kg/s)	N/A	45.32
Loops A and B flow (kg/s)	49.25[a]	47.43
Bypass (%)	N/A	4.45
Loop A flow (kg/s)	24.6[a]	23.57
Loop B flow (kg/s)	24.65[a]	23.86
Pressurizer water level (m)	2.6	2.6
Loop A primary-coolant pump speed (rpm)	776[a]	776.1
Loop B primary-coolant pump speed (rpm)	785[a]	785.4
Primary-coolant flow-control valve	fully open	fully open
Steam-generator-secondary pressure (MPa)	7.3	7.393
Steam-generator-secondary liquid level (m)	10.3	10.3
Steam-generator feedwater temperature (K)	495	495
Steam-generator feedwater and steam flows (kg/s)	2.7	2.76

[a]Information retrieved from data tape.

TABLE II

CHRONOLOGY OF EVENTS FOR RUN SB-CL-05

Event	Test Data (s)	TRAC Results (s)
Break	0	0
Reactor trip	12	N/A
Main steam-line valve closure	15	15
Safety injection signal	17	N/A
Steam-generator feedwater termination	18	17
High-pressure charging injection	31	37
High-pressure safety injection	34	37
Auxiliary feedwater initiation	40	48
Power decrease	45	45
Core uncovery	120-155	140-175
Loops A and B loop-seal clearing	~140	~160
Primary and secondary pressure reversal	~180	~180
Reactor coolant pumps' termination	266	266
Accumulator flow begins	416	416

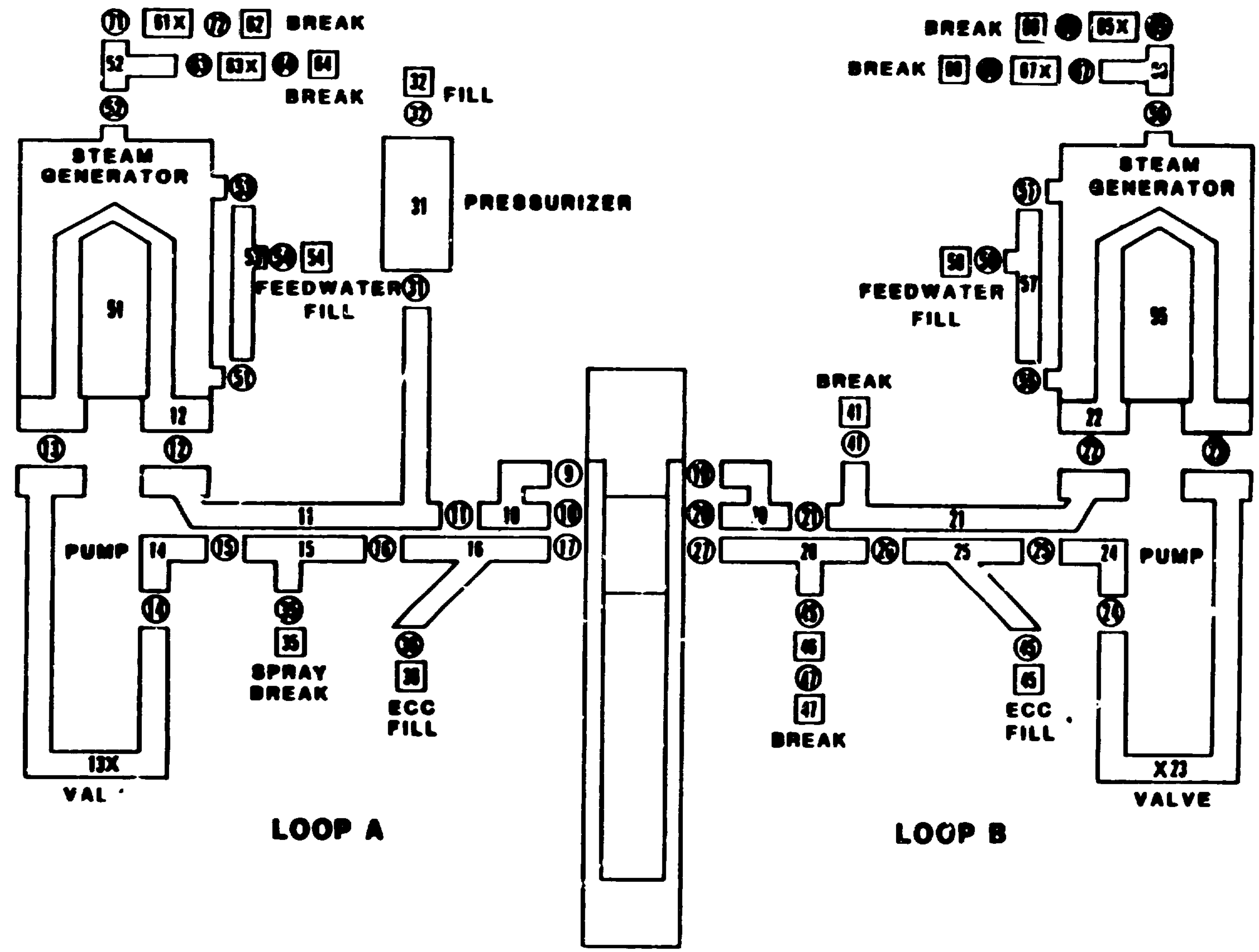

Fig. 1.
TRAC input description of LSTF.

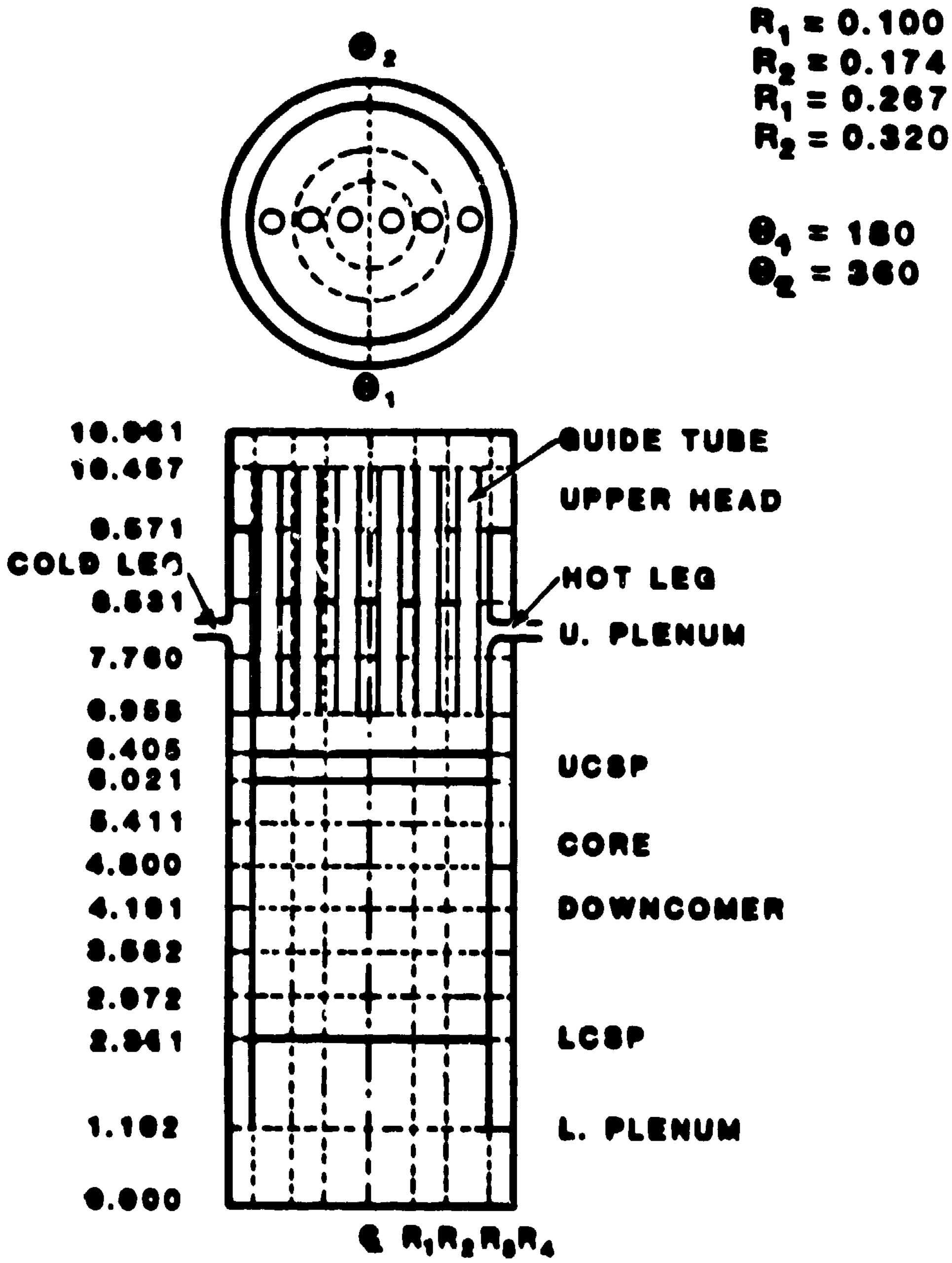

Fig. 2.
Detailed TRAC model of LSTF vessel.

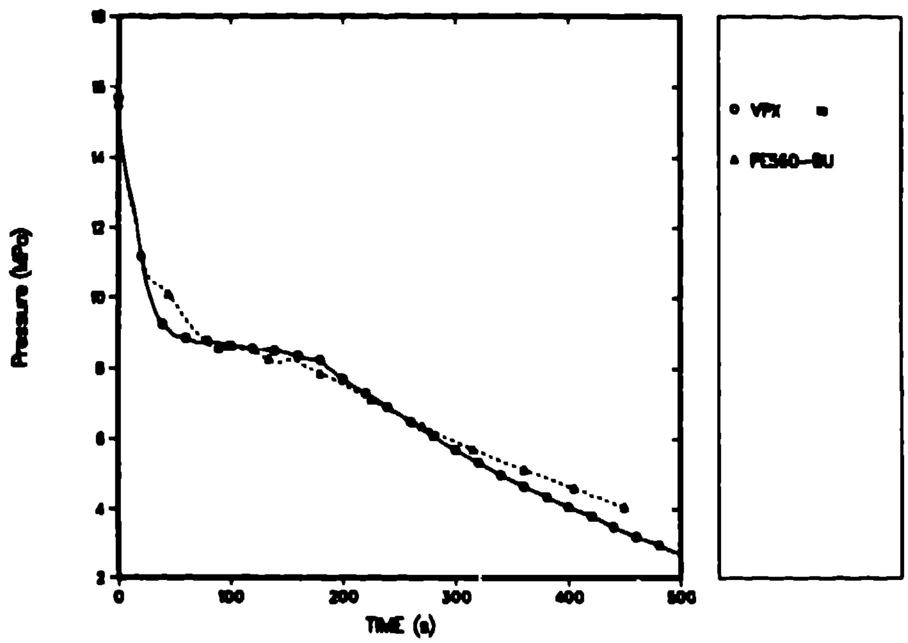

Fig. 3.
Comparison of TRAC-calculated (solid line) and measured (dashed line) upstream break pressure.

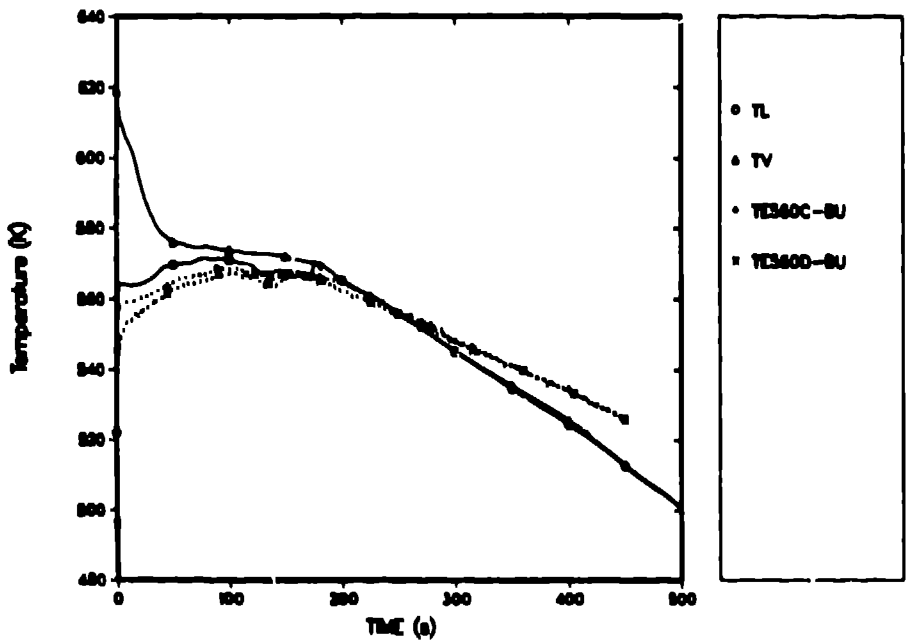

Fig. 4.
Comparison of TRAC-calculated (solid line) and measured (dashed line) upstream break temperature.

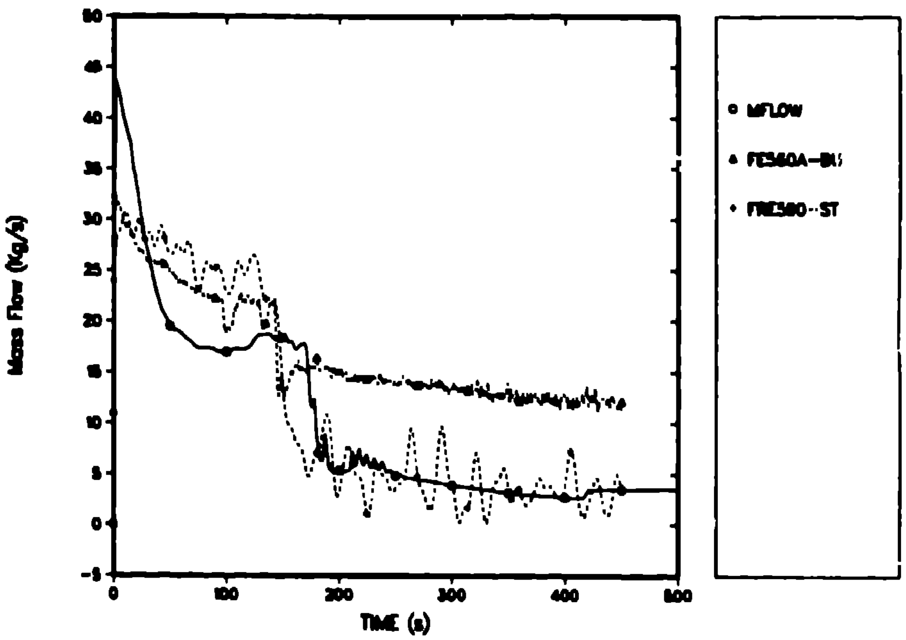

Fig. 5.
Comparison of TRAC-calculated (solid line) and measured (dashed line) break mass flow.

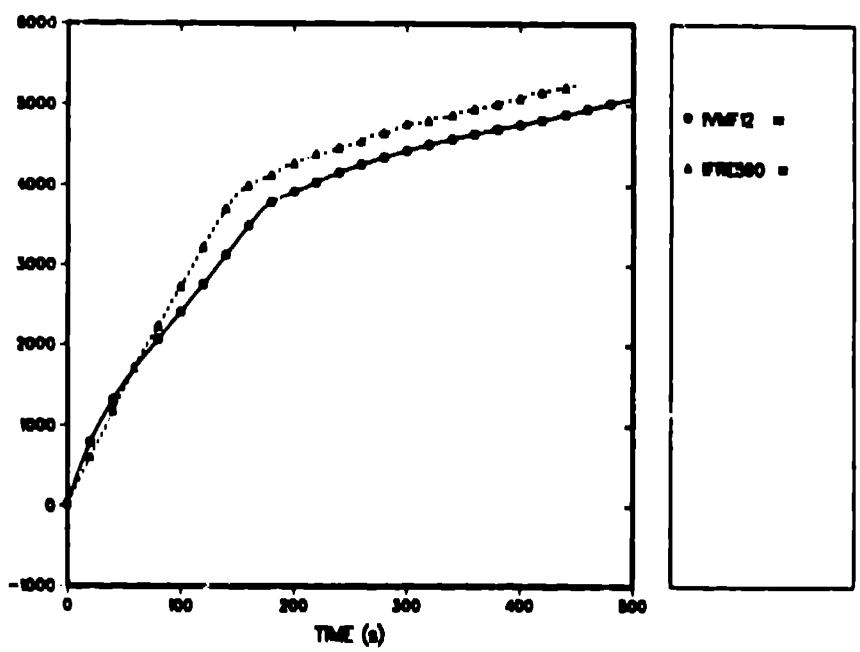

Fig. 6.
Comparison of TRAC-calculated (solid line) and measured (dashed line) mass loss out of break.

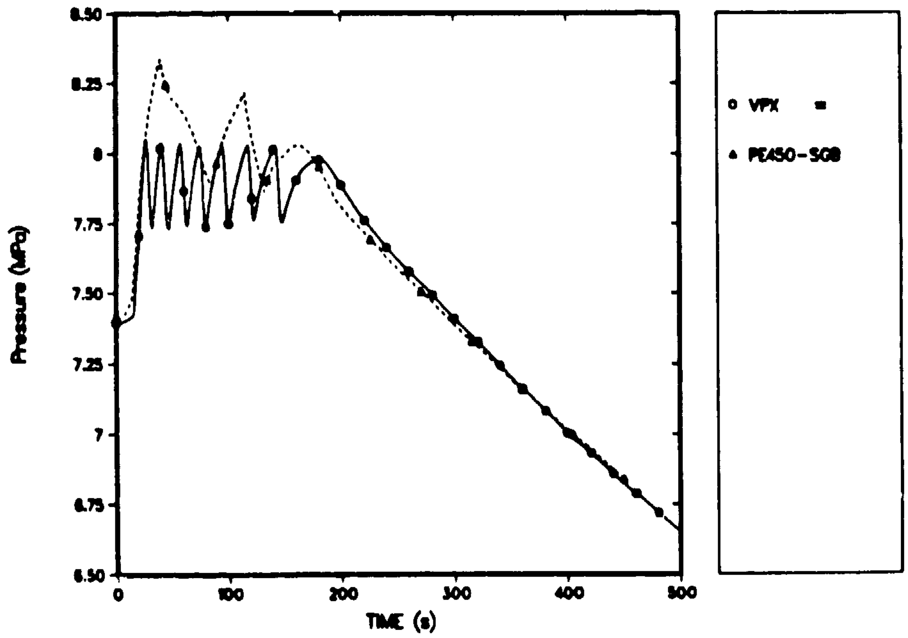

Fig. 7.
Comparison of TRAC-calculated (solid line) and measured (dashed line) steam generator secondary pressure.

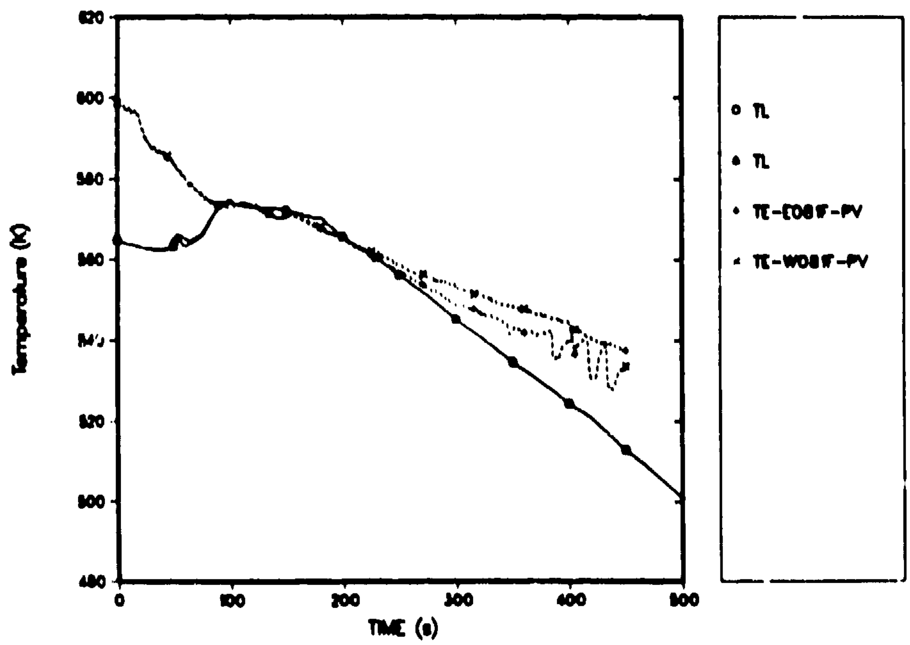

Fig. 8.
Comparison of TRAC-calculated (solid line) and measured (dashed line) upper head temperatures.

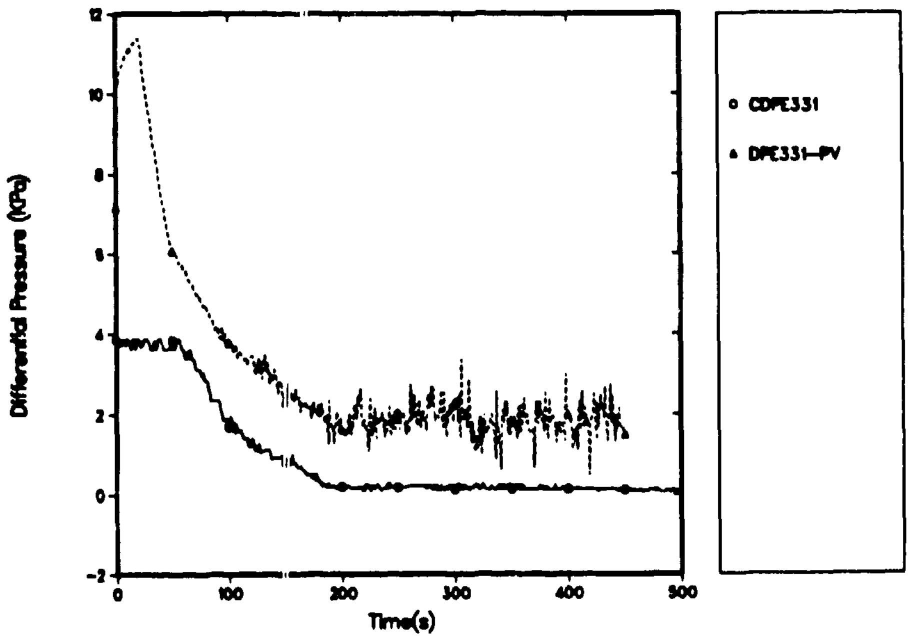

Fig. 9.
Comparison of TRAC-calculated (solid line) and measured (dashed line) upper head differential pressure.

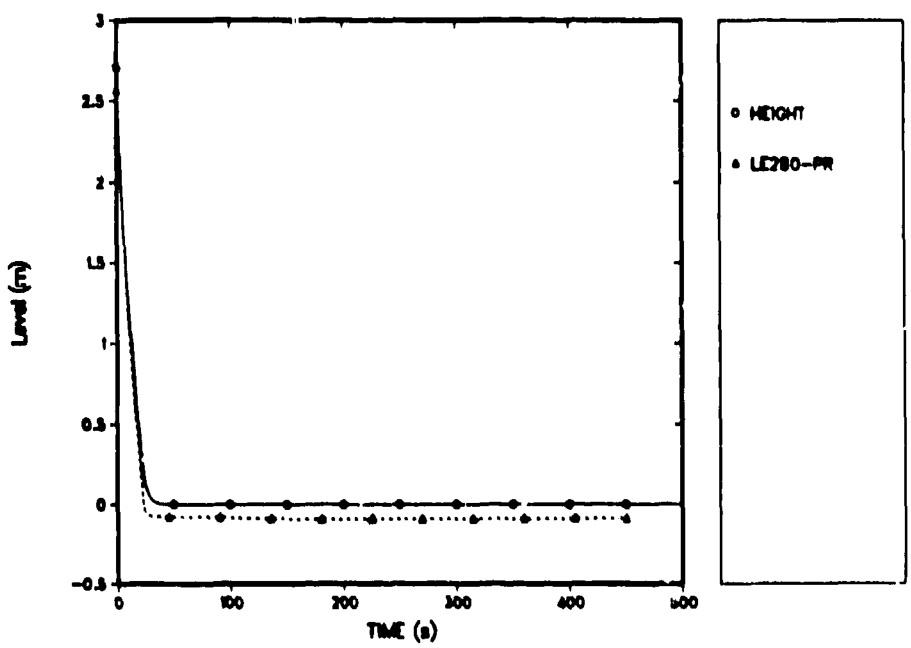

Fig. 10.
Comparison of TRAC-calculated (solid line) and measured (dashed line) pressurizer level

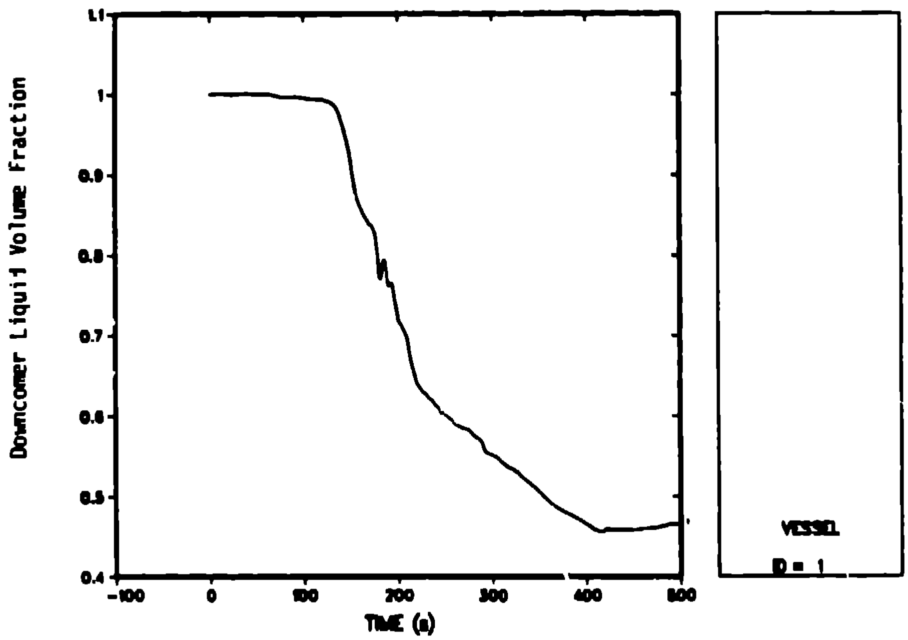

Fig. 11.
Calculated downcomer liquid volume fraction.

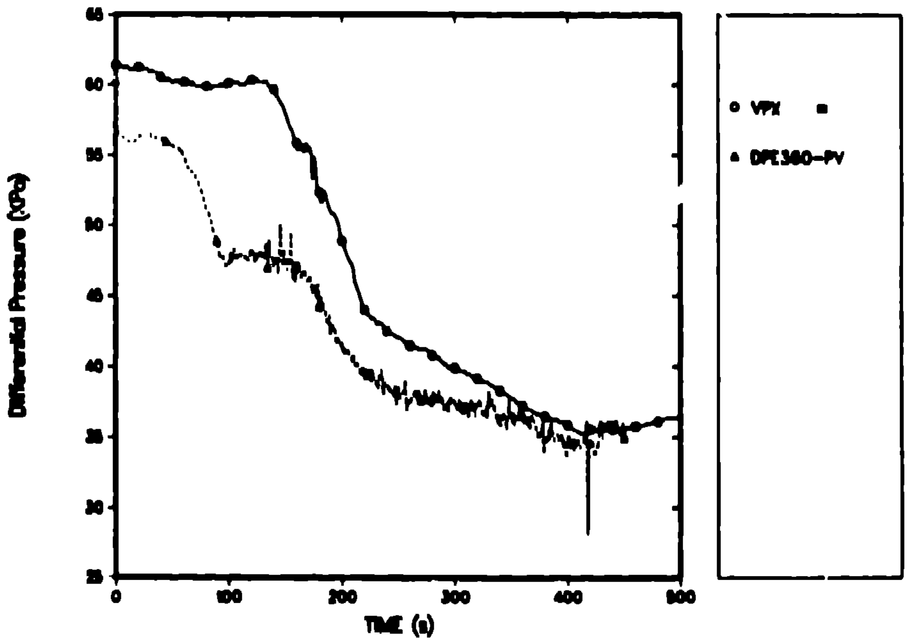

Fig. 12.
Comparison of TRAC-calculated (solid line) and measured (dashed line) downcomer differential pressure.

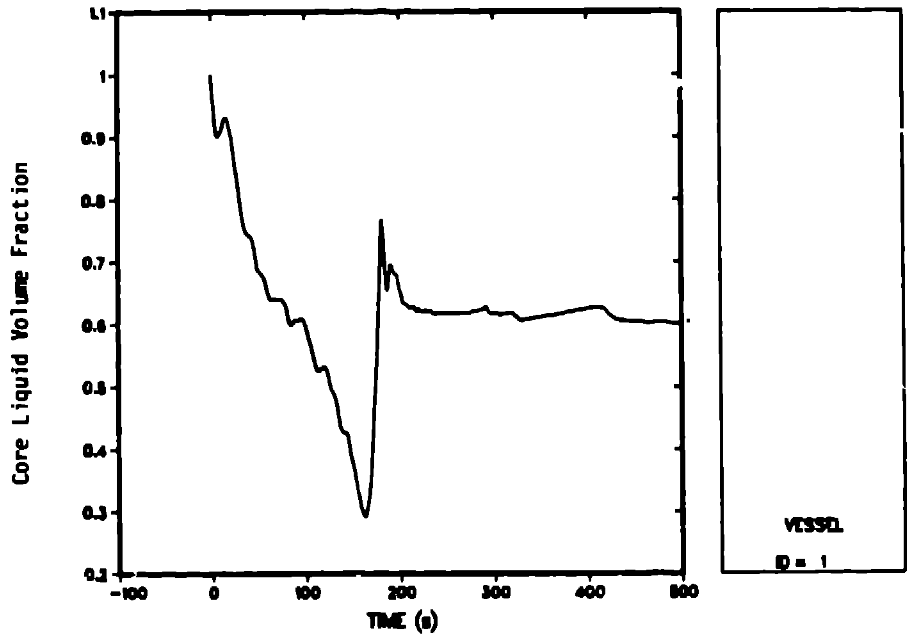

Fig. 13.
Calculated core liquid volume fraction.

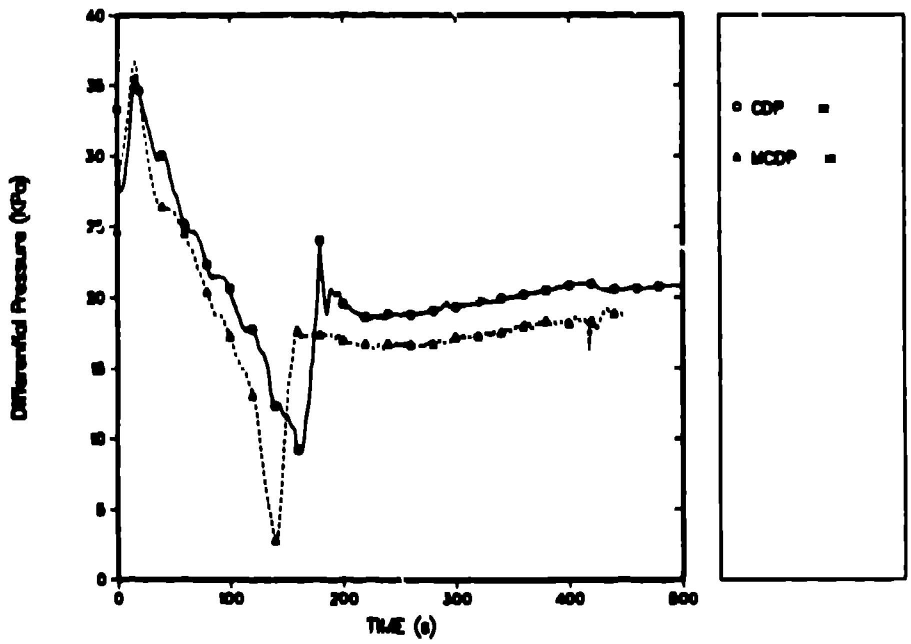

Fig. 14.
Comparison of TRAC-calculated (solid line) and measured (dashed line) core differential pressure.

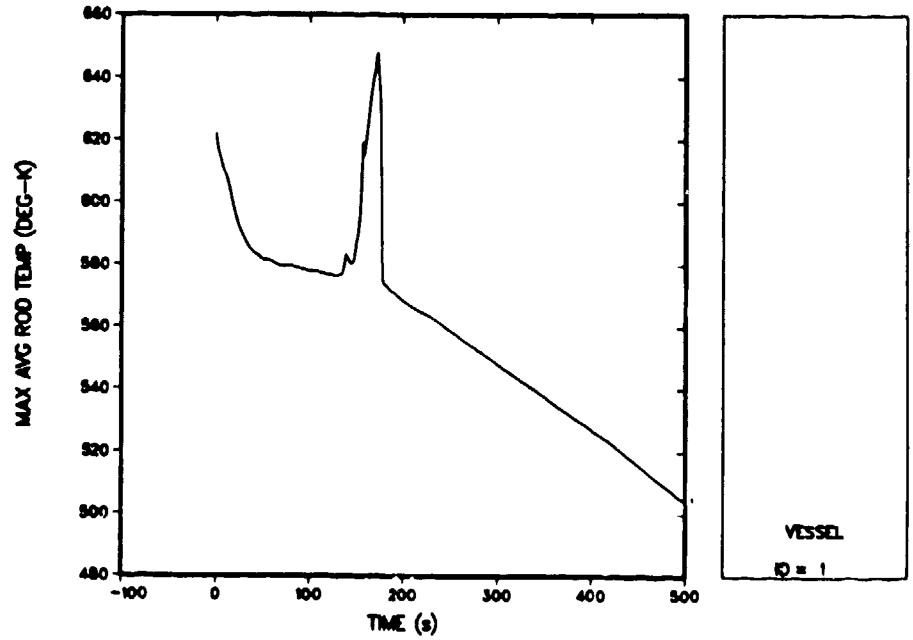

Fig. 15.
Calculated maximum cladding temperature of an average rod.

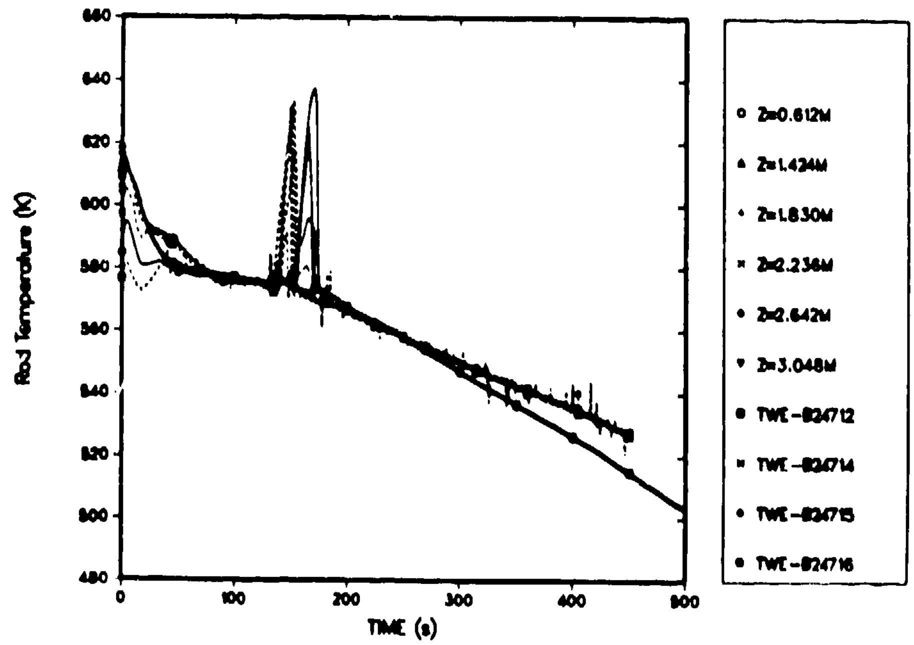

Fig. 16.
Comparison of TRAC-calculated (solid line) and measured (dashed line) rod surface temperatures from bundle 24.

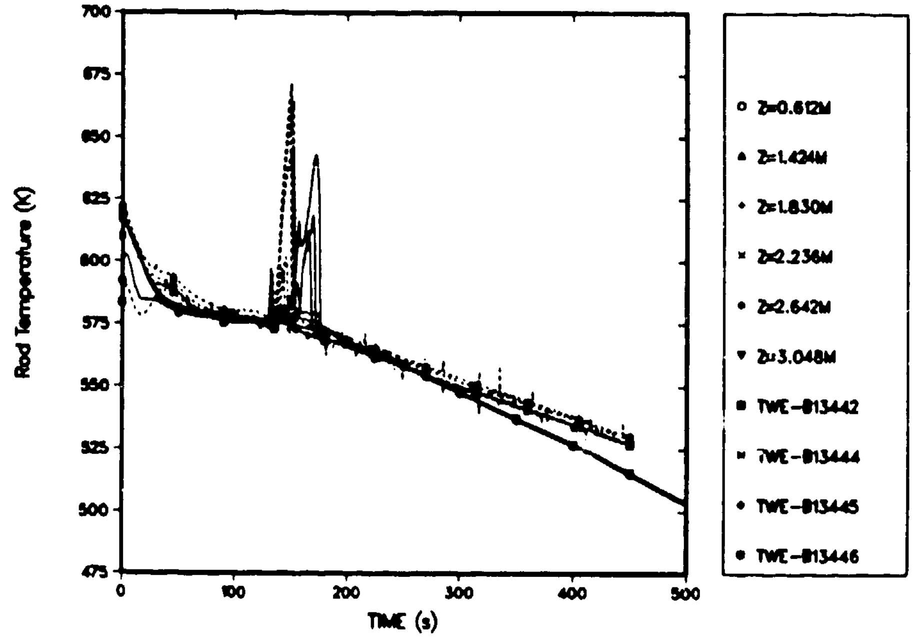

Fig. 17.
Comparison of TRAC-calculated (solid line) and measured (dashed line) rod-surface temperatures from bundle 13.

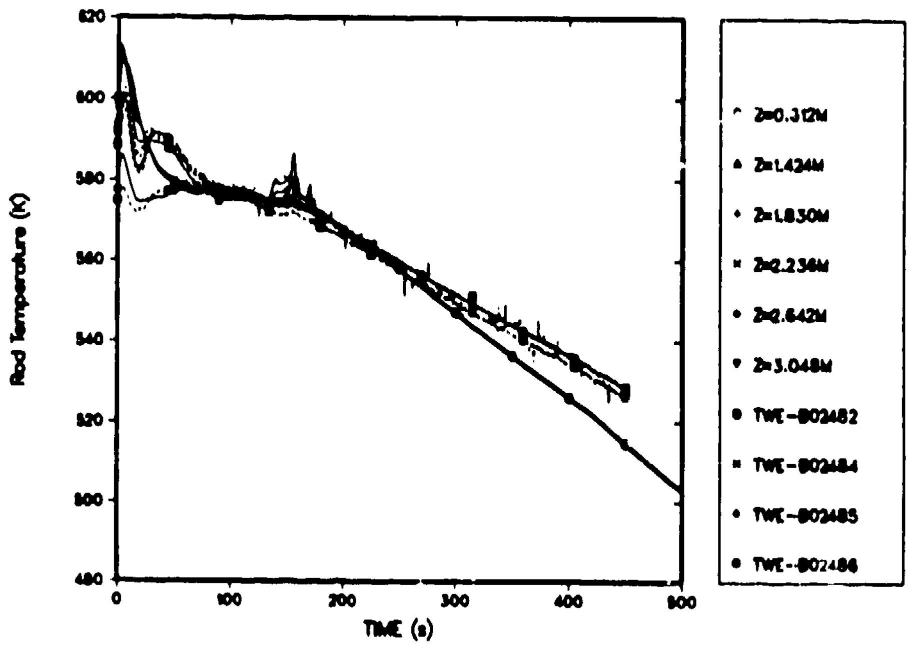

Fig. 18.
Comparison of TRAC-calculated (solid line) and measured (dashed line) rod surface temperature from bundle 2.

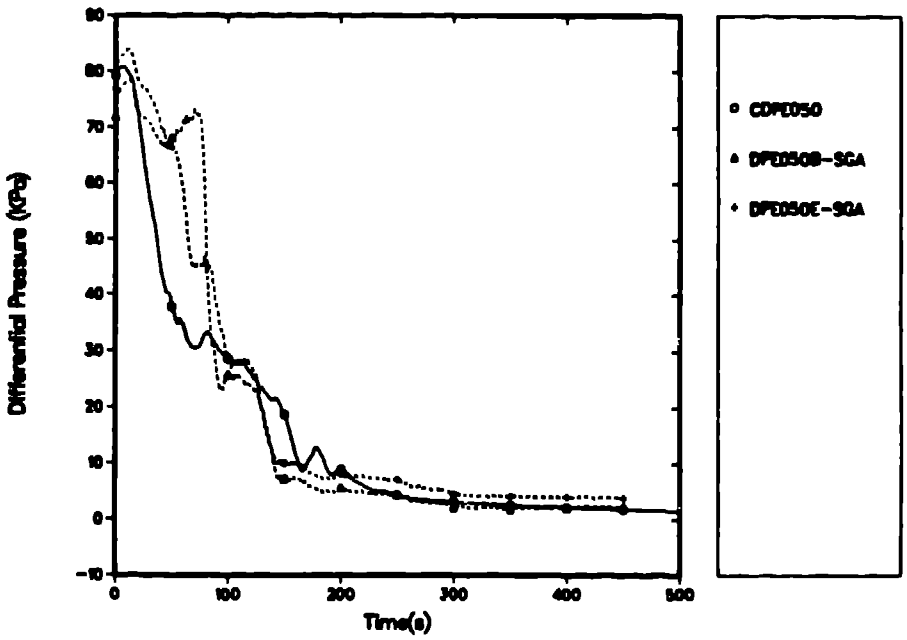

Fig. 19.
Comparison of TRAC-calculated (solid line) and measured (dashed line) Loop A steam generator upflow side differential pressure.

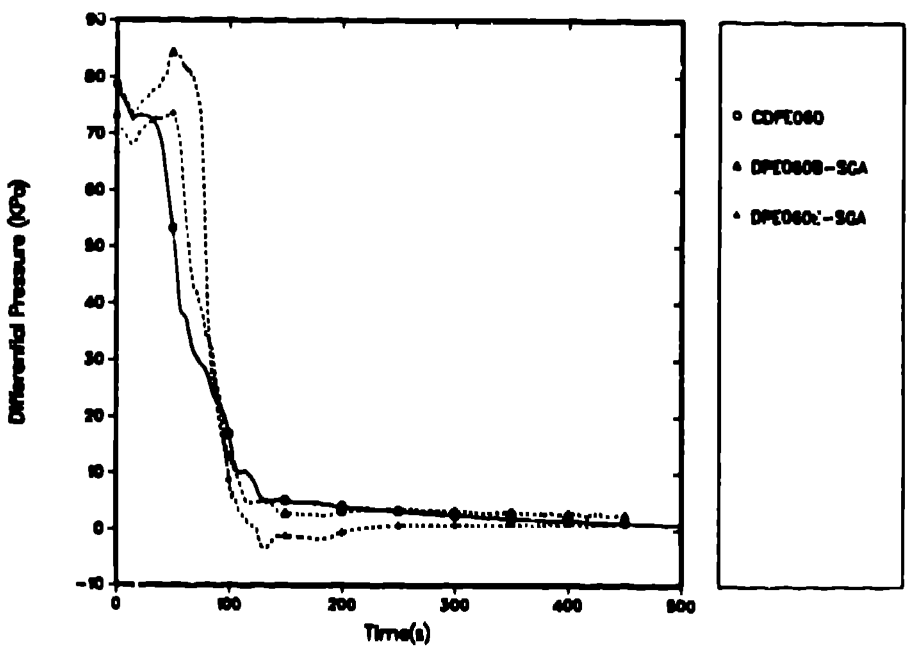

Fig. 20.
Comparison of TRAC-calculated (solid line) and measured (dashed line) Loop A steam generator downflow side differential pressure.

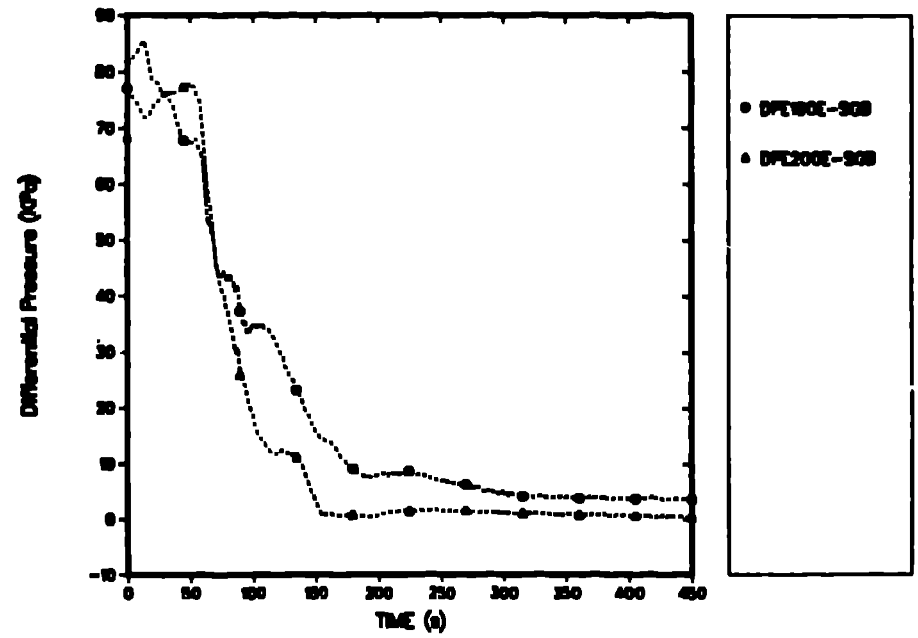

Fig. 21.
Measured liquid holdup in steam generator B.

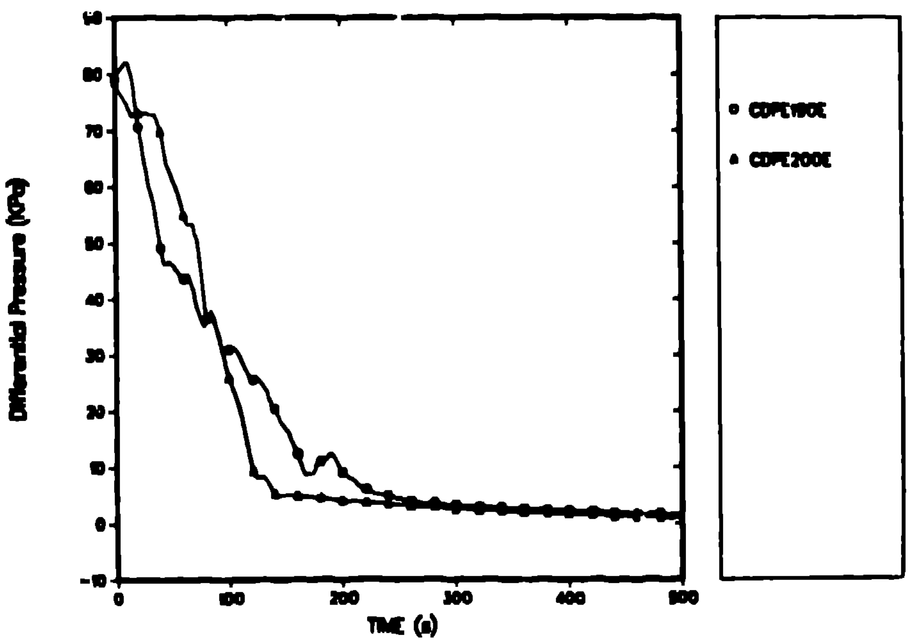

Fig. 22.
TRAC-calculated liquid holdup in steam generator B.

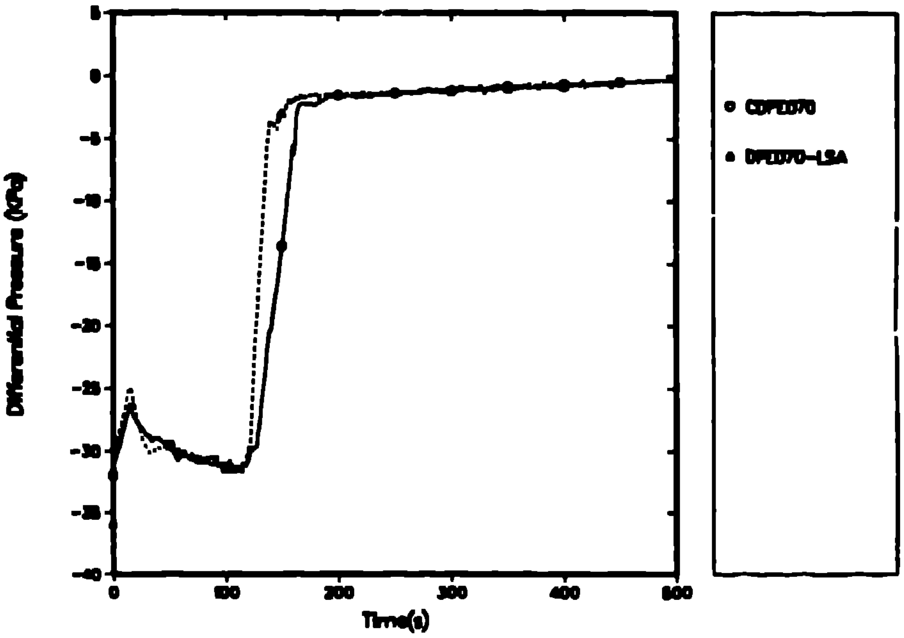

Fig. 23.
Comparison of TRAC-calculated (solid line) and measured (dashed line) Loop A loop seal downflow side differential pressure.

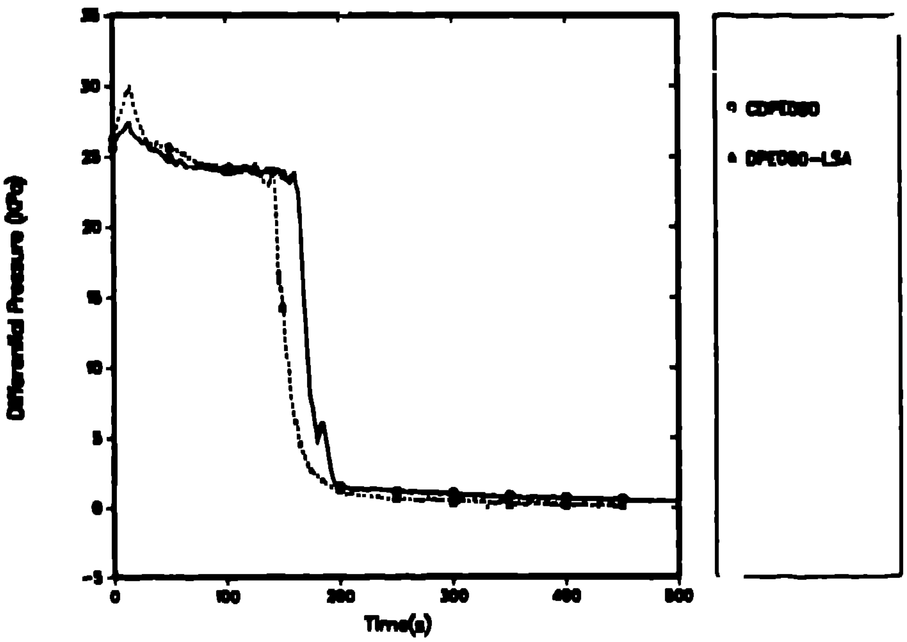

Fig. 24.
Comparison of TRAC-calculated (solid line) and measured (dashed line) Loop A loop seal upflow side differential pressure.

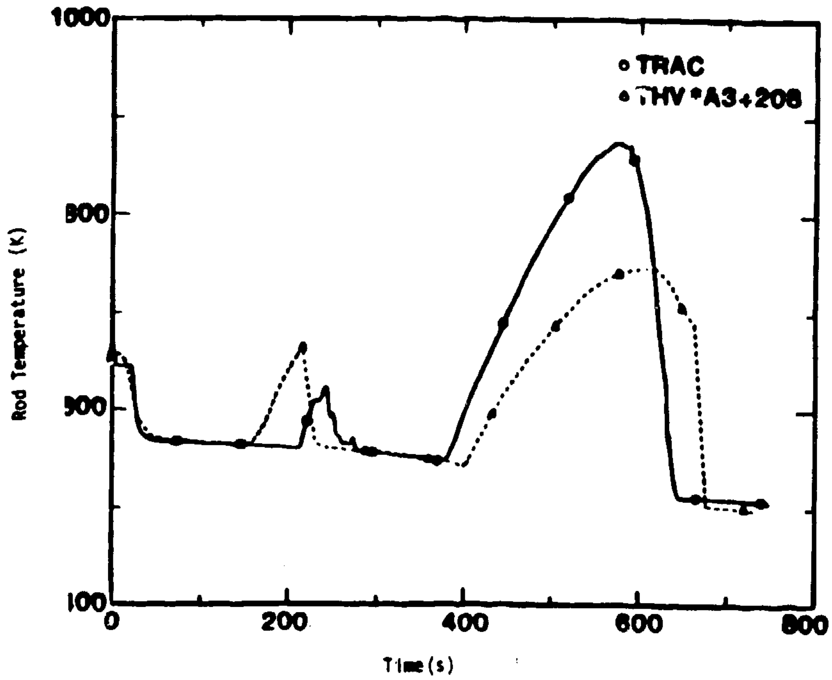

Fig. 25.
Comparison of TRAC-calculated (solid line) and measured (dashed line) collapsed liquid level in the core for Run S-UT-8.

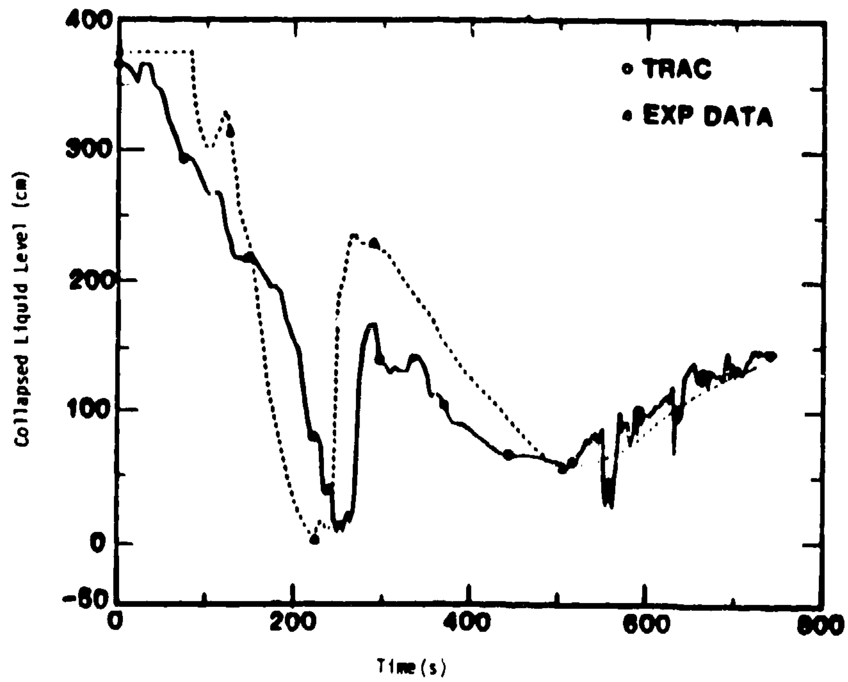

Fig. 26.
Comparison of TRAC-calculated (solid line) and measured (dashed line) rod-surface temperature of rod A3 at the 208-cm elevation for Run S-UT-8.

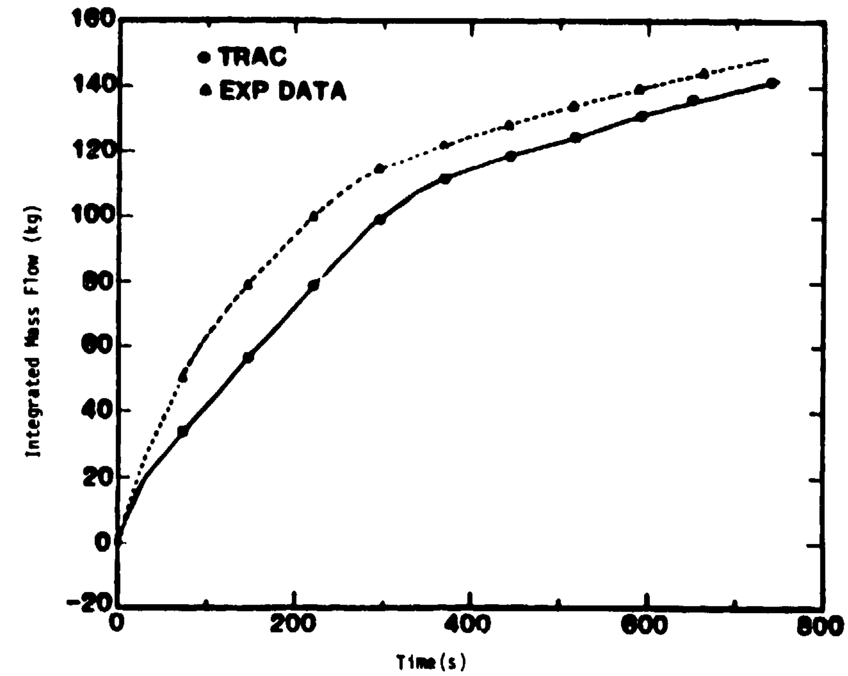

Fig. 27.
Comparison of TRAC-calculated (solid line) and measured (dashed line) mass loss out of break for Run S-UT-8.

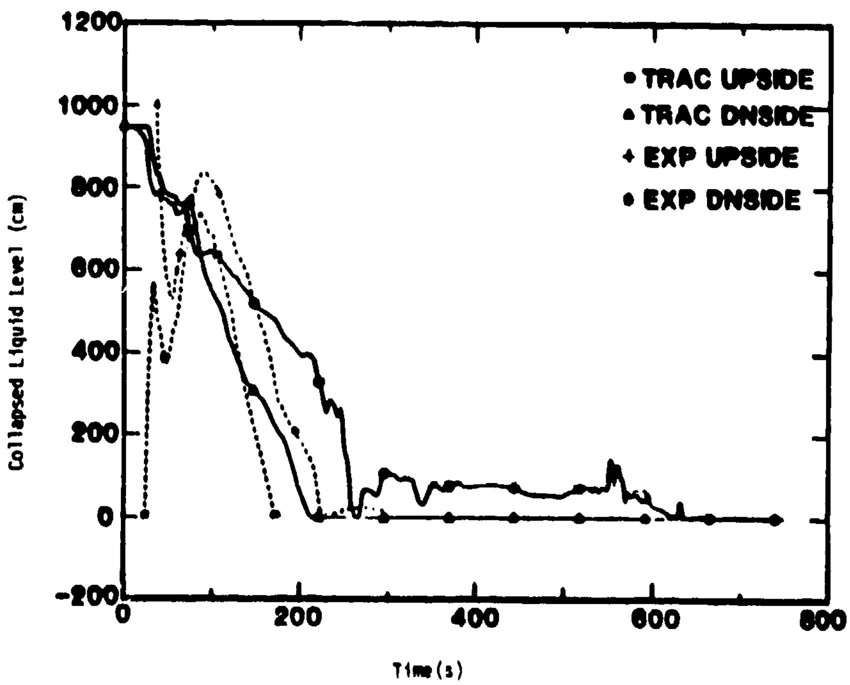

Fig. 28.
Comparison of TRAC-calculated (solid line) and measured (dashed line) liquid holdup in the intact-loop steam generators for Run S-UT-8.